Wind Input, Surface Dissipation And Directional Properties In Shoaling Waves

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LONG-TERM GOAL

We wish to improve our understanding of the physics and interactions which govern the spatial and temporal evolution of surface waves in finite depth water.

SCIENTIFIC OBJECTIVES

1) To measure the direct wind forcing of waves as they advance into shallow water.
2) To measure the evolution of the wavenumber spectrum as the waves shoal.
3) To estimate the kinetic energy dissipation in the surface waters.
4) To determine the dependence of the energy and momentum input into shoaling waves on the wavenumber spectrum and the wind.
5) To determine the dependence of wave dissipation on the wavenumber spectrum and the rate of

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shoaling.

6) To determine the directional response of the wavenumber spectrum on surface current shears and variable bottom bathymetry.

APPROACH

An extensive field program is carried out to study the spectral balance of shoaling ocean waves. Two transects of buoys and platforms measuring directional wave properties over shoaling bathymetry extending to the southeast and northeast out of the Field Research Facility at Duck, NC are deployed to record the evolution of shoaling waves. Two air-sea interaction spar (ASIS) buoys are embedded in the northeast transect and will acquire, in addition to directional wave spectra, observations of meteorological variables (wind stress and stability), and near-surface oceanographic variables (currents, temperature, density and salinity). A third ASIS buoy is deployed at the inshore edge of the southeast transect to provide meteorological measurements and to intercompare different directional wave measurements (directional waverider, bottom pressure array and HF radar). This buoy is also equipped with a string of acoustic Doppler velocimeters and Z-CATs as well as CTDs to measure the mechanical energy dissipation in the water. These dissipation estimates will be compared with those obtained from the nearby located acoustical turbulence spar (Scripps). In addition, measurements of these quantities as a function of fetch, as well as direct measurements of the wind input to the waves, will be obtained from a small SWATH ship equipped with a special boom to measure pressure, flow and turbulence at four levels near the ocean surface and the directional wave spectrum using an array of laser altimeters. These measurements will be used to estimate source terms for wind input and wave dissipation. The measured spectral evolution of the wave field will be compared to calculations based on the action balance equation and incorporating the measured source terms. An HF Doppler radar will measure surface vector currents over most of the domain including the ASIS buoys and directional waveriders. Data will also be collected to estimate directly directional wave properties over the domain at high spatial and temporal resolution. Combining the current measurements with the spectral wave data will be used to estimate the intensity of wave-current interactions and high-resolution bathymetric data will be used to study the variability of wave transformation due to small-scale variations in the bottom topography.

A pilot field experiment (Spring 1999) was carried out to test all system components. The three ASIS buoys were deployed in a joint calibration/validation experiment for passive microwave radiometry (WindSAT). The six week-long deployment took place in the northeastern part of the Gulf of Mexico. The buoys were arranged in a equilateral triangle with a side length of about 15 km. At the center of the triangle was the discus buoy from NDBC (42036). The instrumentation configuration very similar to the configuration used for SHOWEX, the data recording and batteery power systems as well as the ARGOS diagnostic data transmission was extensively tested during this experimental phase.

The SWATH ship is equipped with a boom extending orthogonally out from the starboard side and a mast positioned at the bow. The boom carries a nested laser gauge array to measure the surface elevation. At the end of the boom is a retractable spar which carries sets of pitot tubes, Elliot pressure probes and hot film anemometers at four different vertical levels above the water surface. Additional sets (3) will be placed on rigid poles to measure the influence of flow distortion around the bow. These field trials were conducted last fall (1998) off the coast of Halifax, Nova Scotia.

WORK COMPLETED

1) Two additional ASIS buoy systems (spar and tether buoy) were constructed. Additional structural modifications were added to: **i.** place subsurface turbulence and temperature sensors within the top 5 m; **ii.** struts for profile measurements in the atmospheric boundary layer were rearranged to obtain seven levels and redundancy; **iii.** an outrigger was attached for comparing closely spaced wave gauges outside versus inside the pentagonal cage; **iv.** another lifting point on the foot was added for two-point lifting capability; **v.** changes in the bridle setup for more controlled lifting and ease of attachment to surface tether; **vi.** improved data recording system with more variables based on faster CPU and larger storage capacity; **vii.** increased longevity with battery operation.
2) Installation and testing of data transmission capability via satellite (ARGOS). Presently only diagnostic variables are transmitted to monitor the various sensors on each spar buoy.
3) An extensive pilot field phase was carried out in the northeastern Gulf of Mexico as a joint experiment for passive microwave remote sensing. All aspects of the ASIS buoy system as well as different configurations appropriate for the microwave remote sensing were field tested for six weeks.
4) Final preparations and deployment of all three ASIS buoys for SHOWEX was completed in September and October.
5) Preparation, testing and deployment of two directional waveriders and a MiniMet buoy was completed (Dobson).
6) Final changes were carried on the boom and mast system for the SWATH ship. All systems were attached prior and system checked prior to departure for the SHOWEX experiment (Dobson).
7) Some further preliminary analysis was performed on the ASIS and SWATH pilot experimental phase to verify the integrety of all systems.
8) All ship operations were coordinated with other SHOWEX PIs (Herbers and Melville).
9) The SHOWEX web site was modified and now displays experimental plans, time tables, background information and ship operations for SHOWEX. The web site will be used to exchange data and information among the investigators of the SHOWEX experiment. The web site is located at http://cheyenne.rsmas.miami.edu/showex.

RESULTS

For six weeks (March/April 1999) the three ASIS buoy systems were deployed in the northeastern part of the Gulf of Mexico. The spar buoys were deployed in an equilateral triangle with ~15 km on a side. At the center of the triangle was an NDBC 3-m discus buoy. Figure 1 shows ASIS buoy "*BRAVO*" which was equipped with four acoustic Doppler velocimeters within the top 4 meters and dual sonic anemometers (digital and analog) for intercomparison. Figure 2 shows the fully instrumented ASIS buoy "*BRAVO*" ready for deployment in SHOWEX. Figure 3 displays the time history of the mean wind from the analog sonic anemometers for the three buoys. A faulty battery pack prevented us from

Figure 1: ASIS buoy "BRAVO" with dual sonic anemometers and subsurface turbulence sensors deployed during the GOM99 pilot experiment. In the background is the surface tether and anchored tether buoy.

Figure 2: ASIS buoy "BRAVO" fully instrumented onboard the R/V Oceanus and ready for deployment during SHOWEX. Note the row of six ADVs vertically spaced along the port side of the spar. The bow of the spar is indicated by the red/yellow markings on the top column.

obtaining simultaneous time histories of sonic wind measurments and directional wave properties from all three ASIS buoys. The time histories show several fronts and local thunderstorms that passed over the region with winds reaching 20 m/s. In general the timeseries track very well, but it is noteworthy that differences in wind speed over 15 km can be as much as 2 m/s and more. The high-resolution data will permit us to estimate the advection speed of frontal features and examine the variability of the local directional wave properties. Figure 4 shows an example of the high-resolution frequency wave spectrum from ASIS buoy "*BRAVO*". Note the quality of the one-dimensional energy spectrum which shows an f^{-4} decay for the high frequencies up to about 5 Hz.

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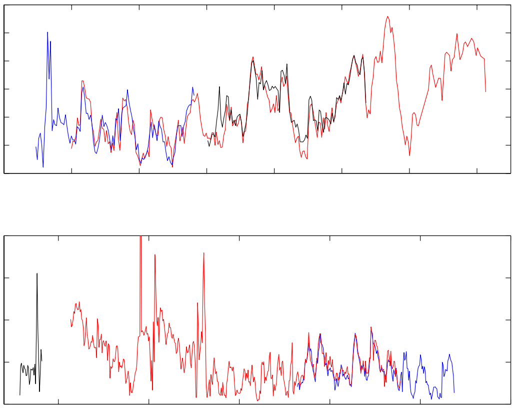

Figure 3: Time histories of mean wind speed from the sonic anemometers on the ASIS buoys in the GOM99 pilot experiment.

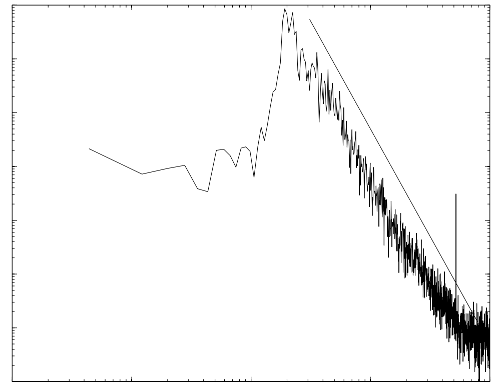

Figure 4: A one-dimensional wave spectrum from ASIS buoy "BRAVO" observed during GOM99

Figure 5 shows the most recent results of uncalibrated mean wind speeds from the three ASIS buoys during the ongoing SHOWEX experiment. The data was obtained via ARGOS transmissions and has not been fully quality controlled. The plot shows the passage of several fronts over the region with winds reaching upto 15 m/s. Furthermore, there are considerable gradients in the wind, with "*YANKEE*" in green being located about 40 km offshore and "*BRAVO*" in blue being located closest to shore. Figure 6 shows a timeseries of the standard deviation of voltage for wave staff 4 on a each of the three ASIS buoys. Note the significant change in voltage during growth and decay periods of the sea state. This variable is used only as a diagnostic. A value of zero would indicate that the wave wire is broken.

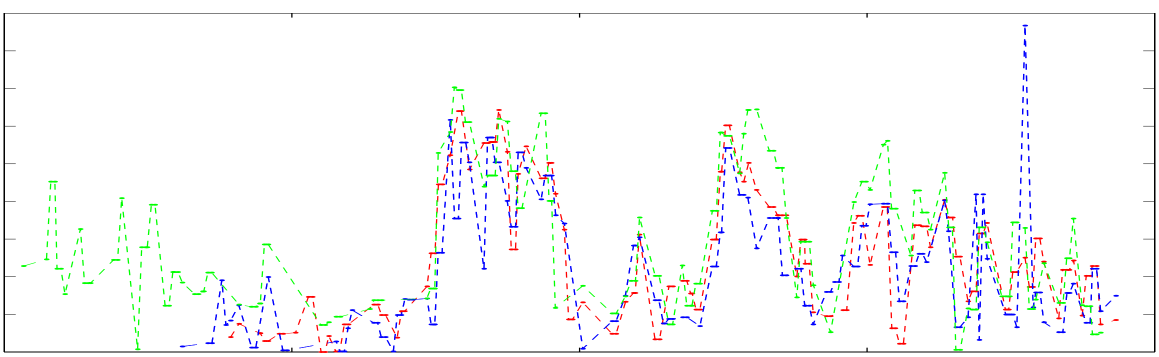

Figure 5: Timeseries of mean sonic wind speed (uncalibrated) as obtained via ARGOS transmissions for SHOWEX.

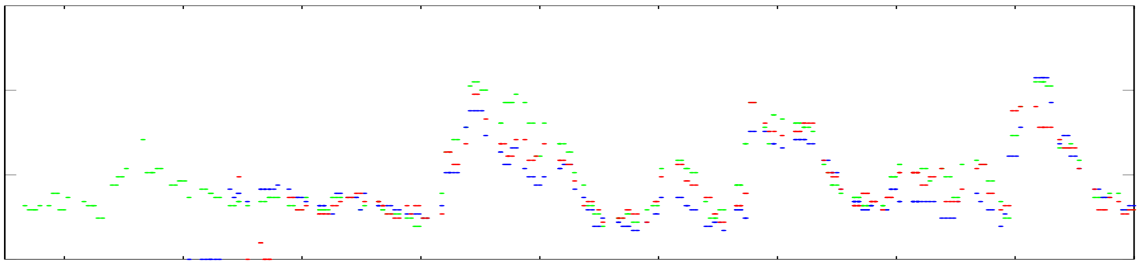

Figure 6: Timeseries of the standard deviation of voltage for wave staff 4 at each of the three ASIS buoys.

IMPACT/APPLICATION

The ASIS buoy system has been tested under a variety of conditions in numerous experiments. Its superb stability characteristics (pitch and roll) makes it a suitable platform for high-resolution air-sea interaction, near-surface turbulence and directional wave measurements. Such measurements are critical to understand mixed-layer dynamics, transport of fluxes across the interface and backscatter issues in microwave and acoustic remote sensing.

TRANSITIONS

None yet.

RELATED PROJECTS

The ASIS buoys were also used in a recent joint calibration/validation experiment for passive microwave radiometry for the upcoming Navy satellite WindSAT.